A geographical tool for personal exposure assessment

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A GEOGRAPHICAL TOOL FOR PERSONAL EXPOSURE ASSESSMENT

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ABSTRACT :

The European policy in urban atmospheric pollution aims at reducing its impact on human health. This problem of public health is closely related to exposure of citizens during the day. Its estimation through persons activities defines the space-time budget. Sooner or later the local authorities in charge of air quality will provide to the population about their collective or individual exposure.
We have developed here a tool that supplies this information. It is based on a multi-source approach. It exploits a Geographic Information System (GIS) gathering information such as individuals mobility, the topographic database, and concentrations of pollutants. Maps and dynamic representations of individual exposure are obtained. They display indoor (home, place of work) and outdoor exposure.

1. INTRODUCTION

Atmospheric pollution becomes a critical factor of anticipated deaths. It concerns ambient air quality as well as air quality in houses and places of work. Pollutants involve pulmonary and even cardiovascular diseases by the most sensible persons as babies, asthmatic and old people. Recently, during the scorching summer 2003 that spread all over the West and Central Europe, more than 30 million people were exposed with episodes of photochemical pollution in France. Sanitary consequences, still badly explained, were without precedent, according to the French Agency of the Environment and the Control of Energy (ADEME 2004).
Policy in European large cities is turned towards the reduction of the sanitary impact. Local organizations in charge of air quality monitoring have to study the effects of air pollutants. Hence for the well being of human and for the population information, it is needed to evaluate the actual exposure of persons to ambient pollution. One way to perform it is to evaluate the space-time budget of air pollution exposition. The space-time budget is defined as the estimation of the persons exposure to air pollution through their activities during a day.
Most large cities in Europe have acquired a monitoring network for air quality. A network is composed of static measuring stations. It allows a continuous monitoring of air pollution on station location. Pollution data are collected in near real time and used to compute a global atmospheric pollution indicator, called ATMO in France. This indicator aims at informing local authorities, as well as the population, of the atmospheric air quality. In answer to a high rating of this indicator, public authorities are able to take restrictive measures with car traffic and with some air polluting companies in order to minimize the impact on public health.
The agencies of air quality monitoring organize series of measurements of the exposure to air pollution. Measurements are taken thanks to mobile sensors carried by people during their activities in one day (AIRPARIF 2001). Such campaign allows a better understanding of the time of exposure spent in contact with high levels.

Measuring campaigns and global atmospheric pollution indicator are not efficient enough either to assess collective or individual exposure or to inform the population. The global atmospheric pollution indicator aims at informing the population about the air quality but not about the risks of exposure. Moreover the mobility of persons or indoor and outdoor activities are not taken into account in the calculation of the level of pollution. To overcome those problems, a geographical tool is proposed.
The first section gives explanation on the area studied, data and tools used. In this section, the multi-sources approach is presented. Then a first implementation of this tool is shown followed by a discussion about the results obtained. The last section concludes and proposes the future works.

2. STUDY AREA, DATA AND TOOLS

The work presented here, relates to the development of a software tool aiming at establishing a space-time assessment of the personal exposure to the atmospheric pollutants, for a citizen, for a given day. Studies, as the so-called "sentinels of the air" which was held from summer 2001 to winter 2002, (http://www.appanpc-asso.org/index_FR.htm) aim to better evaluating the individual exposure to air pollution through series of national measurements. They supplement fixed measurements of pollutants realized in the ambient air by air quality monitoring networks. They take into account displacements of the inhabitants within the agglomerations (by the means of portable sensors for example), as well as the contribution of indoor pollution in buildings (thanks to fixed sensors). Our approach is different since it consists in modelling the individual exposure of a particular citizen, during one day thanks to a geographical information system (GIS).
The study area is the city of Strasbourg, France. It is located in Eastern France near the German frontier. Geographical coordinates are 48°35'04" latitude North and 07°44'55" longitude West. It counts 451223 inhabitants according to the last census in 1999 and has a temperate climate dominated by continental influences. Atmospheric pollution in Strasbourg is mostly due to motor vehicles.

DATA :
It is pollutants concentrations of ambient and indoor air, spatial data such as geographical, topographic or satellite data, and also data on the exposure such as indexes, standards and thresholds. Our database is based on an urban topographic data base (BDTOPO®) provided by the French national geographic institute (IGN©). Pollutants concentrations measurements of ambient air are provided by ASPA (Association for the Monitoring and the study of Air Pollution in Alsace, http://www.atmo-alsace.net) and those concerning indoor air are provided by OQAI (Observatory of Indoor Air Quality, http://www.air-interieur.org).
BD TOPO® is a reference database including the physical three-dimensional description of a territory. It is the necessary topographic component to build up localised information systems. It has a metric precision. This base contains eight principal topics : roads, the electrical supply network of transport, hydrography, buildings, vegetation, the description of the relief, administrative limits and finally toponymy.
Data concerning outdoor pollution relates to specific measurements of pollutants (SO2, Nox, O3, PM2,5, PM10, PM13) catches on the 11 fixed measuring stations distributed over our area of study. In fact stations measure at the same time the background and the local pollution. In addition to the concentrations of pollutants, they also provide weather data such as wind speed, relative humidity, air temperature or solar radiation... The pollutants concentrations are provided for each measuring station every ¼ hour during one day. This data is collected by the local measurement network of ASPA.
Indoor air pollution can be approximated as a ratio between the pollutant concentration inside and its concentration outside (Mosqueron, Nedellec 2001, AIRPARIF 2001). This ratio depends on the pollutant, the type of building, season, system of air renewal, presence or not of smokers and presence or not of sources of pollution inside. Thanks to the BD TOPO®, buildings can be characterized in three classes. Thus the ratios can be applied to pollutants concentrations observed outside.
Norms and thresholds of exposure used are those advisable by the World Health Organization (WHO).

TOOLS :
The evaluation of a citizen personal exposure during the day requires to combine his exposure at the same time to outdoor and indoor pollutants. An index of exposure allows to quantify the degree of harmfulness of this exposure. Although the air pollution is a complex phenomenon related to the presence of many pollutants in ambient air, such indexes aim to lay out synthetic information on the background urban pollution by means of only one indicator. Unfortunately, data and studies on indoor air quality are very rare and no index dedicated to this pollution exists. The ATMO index is only related to ambient air pollution and does not really take into account personal exposure. Therefore only the followed expression of exposure is used for the assessment :

$$E = \sum_{i=1}^{N} C_i . t_i$$

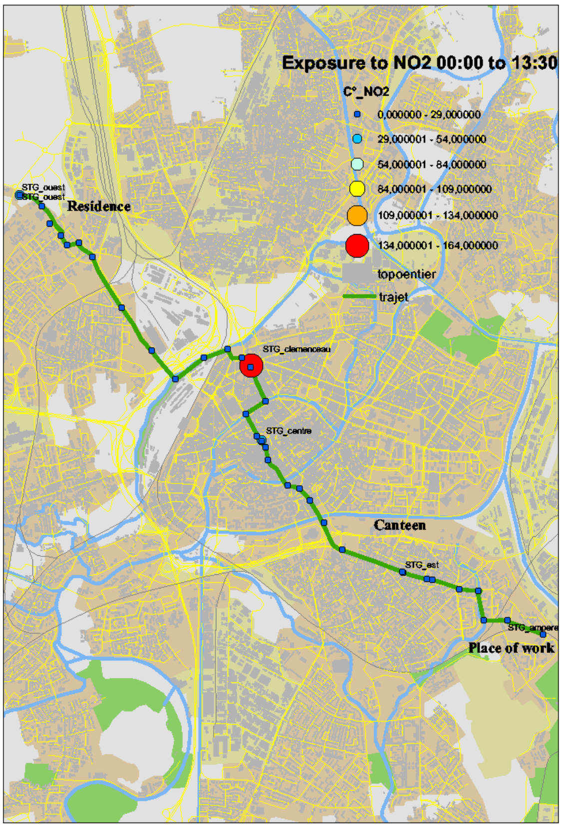
with i indicating a pollutant, C_i its concentration, t_i the time spent in contact with this pollutant and N the number of pollutants.

Thanks to the Tracking Analyst module, extension of ArcGIS™ 8.3, a geographical information system, it is possible to manage, represent and analyse temporal phenomena. The Tracking Analyst module allows to manage data on mobility and the evolution of pollutants concentration in time. Then a dynamical representation is created in order to display the rates of pollutants to which a citizen is subjected throughout his way. This tool works also with real time data supplied by a connection to the Internet.

3. RESULTS AND DISCUSSION

Our work is demonstrated on the town of Strasbourg but can be generalized at any city having a topographic database as well as an air quality monitoring network. The simulation is based on the topographic database of Strasbourg (BDTOPO®), measurements of pollutants concentrations taken by the ASPA, Association for the Monitoring and the study of Air Pollution in Alsace, data of indoor air pollution of OQAI (Observatory of Indoor Air Quality).
The following map (figures 1) is obtained. Figure 2 is a snapshots of the dynamic representation acquired with the Tracking Analyst module. It represents the daily exposure to the NO2 of a member of the active population of Strasbourg during the half-day of August 14, 2001. This citizen goes from its residence located in the North-West of Strasbourg to its place of work located in South-east. He thus crosses the city to foot every day. Its way lasts 1 hour in the morning from 8h to 9h and 1 hour in the evening from 17h30 to 18h30. He stays 8 hours at its place of work, spends 2 hours outside and the rest of its time in its residence. The map shows its exposure to the NO2 from 13h30 to midnight along its way place of work/residence, and also at its place of work and its residence. The colourful disks on the map show the quantity of pollutants to which he is subjected. By the same, it shows the air quality he breathes at this precise place and this moment t. Others maps have been obtained that represent the exposure to other indicators of pollution as ozone and fine particles (O3, PM).

Exposure to NO2 of a member of active population for half day



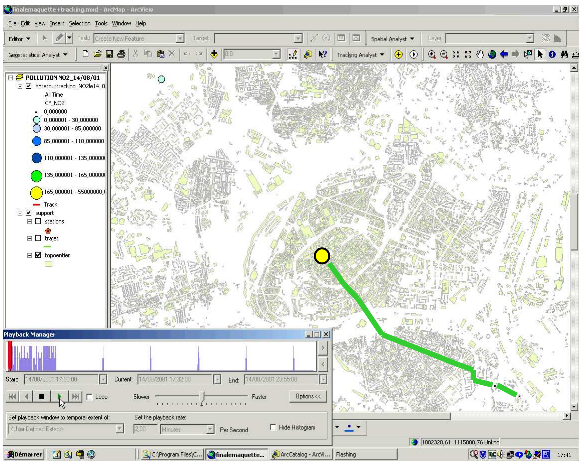


Figure 1 (left). Representation of the exposure to NO2 during a half day. In background of map, the whole buildings are visible issued from BD TOPO®, the blue feature represents the way taken by the citizen to go from his place of work to his residence, the colourful disks represent the quantity of pollutants to which he is subjected outside and inside the buildings.
Figure 2 (right). Snapshot of the animation. The way in green and the colourful disks appear progressively. In the bottom left corner, the progression bar allows to display the time and to manage the animation, to stop it at a precise place or moment to zoom in, for example.

The exposure to pollution during one day remains difficult to estimate. To improve it, more realistic data of mobility would be needed, more information on the sanitary risks. Actually many data concerning indoor air quality are missing. Only few documents are available on this subject. It would seem that the majority of the studies launched on the exposure to indoor air are exploratory. It is only recently that the effects of this pollution are taken into account in calculation of the individual exposure. Consequently, there are not practically sanitary data, or concentrations. Neither thresholds of exposure, nor thresholds of recommendations can be defined. The principal problem is the absence of indoor pollution indicators (Kirchner 2003). By studying the space-time budget of the working population to some air pollutants in six European cities, Expolis (Air Pollution Exposure Distributions of Adult Urban Populations in Europe), a study in progress, hopes to define indicators (http://www.ktl.fi/expolis/expolis2000/42.html). An other major problem is the lack of pollution map at city scale. With such a map, the exposure could be assessed at every places and every instants. Nevertheless this work offers an original approach of the exposure assessment. It does not pretend to integrate all available data but to show a tool that could become a decision or information support system.

4. CONCLUSIONS

This dynamical representation brings out that the principal problem is the lack of concentration data that covers all the city. In particular, it does not exist any exposure data for indoor pollution. Pollutants spatialization and distribution on urban area have to be studied in order to know the concentration at any point and at any moment in the city. Indoor air quality remains important regarding the sanitary impact and has to be assessed.
This first implementation also shows that useful tools are available and are promising to model exposure. GIS is notably a technology in full rise which becomes increasingly convivial and which proposes many functionalities. Moreover, digital maps and geographical data become accessible and cover the territory more and more largely. Thus the precise localization of a person becomes all the more possible (Jensen 1999).
Regarding the exploitations of the tool presented here, they are numerous. Many scenarii can be imagined. A person who wants to know his exposure to the atmospheric pollutants, i.e. the sanitary risks along a way downtown or for a particular day, could visualize on his computer or telephone screen, such a representation of the exposure combined with a route calculation system. The purpose of this modelling is to give individualized information on the air quality that a person breaths during a day, to calculate his exposure and thus to give him recommendations. These recommendations can relate to spot or hours to avoid such a day. This representation is also addressed to the local authorities. By the means of this system, they can manage exposure data, analyze them and provide information or recommendations to the population. Thanks to the Tracking Analyst, it can be possible to receive real time data on pollution and then to diffuse information through the internet. We limited our study to the calculation of an index over one day. But thanks to the calculative capacities of the mobile telephones, it would be easy to propose to citizens exposure indices over 10 days or 1 month.

6. REFERENCES

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